

Parcel Accuracy Enhancement Plan Prepared for The City of Billings Fall 2006

A partnership project of
Yellowstone County,
City of Billings,
Montana Department of Administration ITSD, GIS Bureau,
US Department of the Interior, Bureau of Land

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Project Background

Who, What, When, Where, How, Why

I. a Stakeholders, interested & affected parties, contributors

History:

The cadastral parcel data were originally mapped and geo-referenced to digitized section corners taken from 1:24,000 scale US Geological Survey Topographical maps. Several years ago the data were re-adjusted to the Bureau of Land Management's Geographic Coordinate Data Base (GCDB) coordinates, which resulted in the cadastral data shifting somewhat. The entire city was mapped and the parcel data is sufficiently accuracy for most purposes, however, the cadastral data do not align well with other more spatially accurate GIS data such as aerial imagery and public works infrastructure data. Because of the misalignments some spatial analysis does not yield accurate results, and in many parts of the city the misalignment against the aerial imagery infers incorrect property alignment.



I. b Project Area Status maps - pre-adjustment

The following maps describe present conditions that are useful for consideration regarding the issues addressed in this report.

- I.b.i Parcel Density
- I.b.ii Population Density
- I.b.iii Property Value

II Project Problem statement

II. a Issues

Project/Task Objectives and Requirements

The primary goal of this project was to develop a plan for how to improve the spatial accuracy of the cadastral layer for the City of Billings. We explored a couple processes for improving the spatial accuracy - a GCDB based process and an aerial imagery based process. The GCDB process was explored due to the GCDB serving as the initial basis for the parcel mapping. With the GCDB as the control framework for the placement and orientation of parcel data, it is logical to assume that improving the accuracy of the GCDB will result in a more accurate parcel layer. There are some problems with this process in urban areas and densely developed communities however, due to the difficulty in finding monumented PLSS corners in highly developed areas, and because the density of parcels tends to reduce the influence that the GCDB has on the cadastral layer. This is likely due to the lineage of the parcels in urban areas. As sections of land become more densely subdivided fewer direct connections are made to the Public Lands Survey System corners - especially where construction destroys monuments. Therefore as a section of land becomes more densely developed the references tend to *infer* a tie - that is, the ties are referential rather than physical (e.g. a tie may be to a subdivision corner that was tied to a section corner, rather than tying the section corner itself). As more subdivisions are developed over time the ties to the PLSS may become further and further removed from reality. The outcome of this is a cadastral layer that, though legally connected to the PLSS, is only loosely connected to the PLSS in urban areas. Thus, improvements to the spatial accuracy of the GCDB (coordinate representation of the PLSS) may have only a minor affect on the spatial accuracy of the parcels that are referentially tied to it. Therefore it becomes necessary to explore other methods for controlling the parcel mapping in urban areas. To that end, a pilot project of one section in the city (T01N R25E Section 33) was used to test two methodologies - a GCDB based method and a method using aerial imagery as the control.

It is important to note that the spatial accuracy of the parcel data will always be worse than that of the reference data used to control. That is, regardless of the source of the control (GCDB, aerial imagery, etc.) the parcel data can not be more spatially accurate than that and is most likely to be less accurate with regard to the spatial location of the GIS layers in coordinate space. For example, if the parcels are adjusted to fit aerial imagery that is horizontally accurate to within 5 feet, the parcels will be accurate to within 5 feet in the best cases, and on average is likely to be less accurate than 5 feet.

II. b Goals & Objectives

The goals in the pilot project were to compare the time, cost and results of the two methods, in order to make recommendations for the more cost effect process to use to show a major improvement in the spatial accuracy of the city parcel layer. The pilot project assessed the spatial accuracy of the two varieties of aerial imagery that the city had and performed a spatial adjustment to the more accurate set of

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imagery. Additionally, PLSS corners were GPS (to cm accuracy) and the GCDB was adjusted to the improved coordinates.

- II. c Project Area Status maps - post-adjustment
 - II.c.i GCDB/Parcel Accuracy
 - II.c.ii Changes wrought (pre to post adjustment)

III Approach used

III. a Methods, Options, Procedures to Used for Enhancement

Two methods were used to adjust data so that the work, costs, and results could be compared for the sake of evaluating options and providing recommendations for completing the remainder of the city's parcels. The two methods used were an adjustment to aerial photography and a GCDB based adjustment.

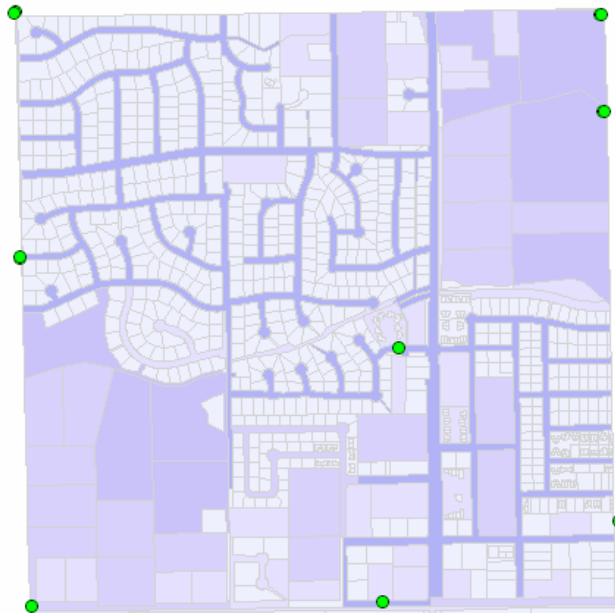
III. b Aerial Photography Adjustment:

The City of Billings has aerial imagery from the USDA National Aerial Imagery Program (NAIP), Digital Globe, and, along the Yellowstone River, the Yellowstone River Corridor Digital Photography. DJ&A assessed the spatial accuracy of the NAIP and Digital Globe (DG) imagery by performing GPS surveys on photo identifiable points.

DJ&A, PC performed an accuracy assessment to determine the horizontal positional accuracy of the various aerial imagery data sets that cover the City of Billings, Montana, in order to support adjusting the parcel GIS layer. The ultimate goal was to compare a Geographic Coordinate Database (GCDB) adjustment to an adjustment to the most accurate aerial imagery, in order to determine the more cost effective procedure for improving the spatial accuracy of the GIS parcel lines.

The method used to determine the positional accuracy of the various imagery data sets was a ground-truthing procedure using survey accuracy GPS to field collect accurate coordinates on photo visible discrete features then compare those GPS coordinates to coordinate values picked off the digital image using ArcMap.

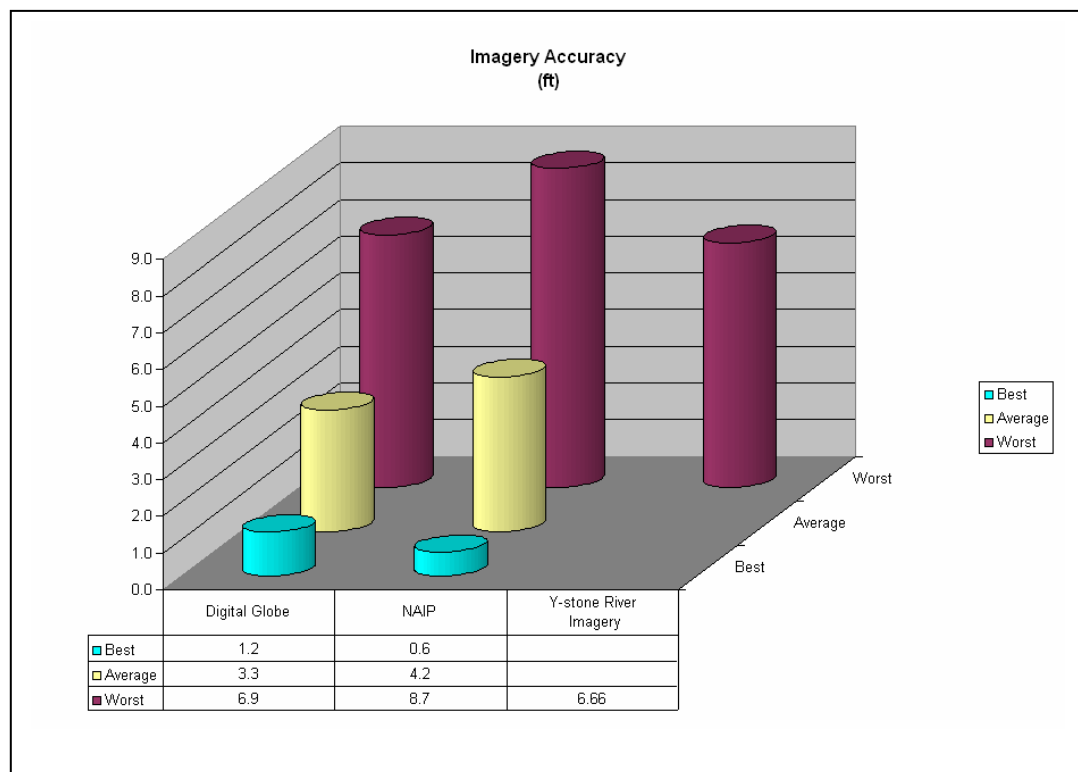
Points were selected to be inside of and completely contain the pilot test area (T01NR25E Sec 33), as shown below.



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We compared the National Agricultural Imagery Program (NAIP) aerial photography to the Digital Globe Satellite Imagery (DG). Both data sets are full color imagery. The NAIP has resolution is 1 meter pixel "with a horizontal accuracy that matches within five meters of a reference Roth image". The Digital Globe imagery has a 0.6 meter (~2 ft) pixel resolution, but the DG metadata did not state a spatial accuracy. Because it is easier to resolve discrete features on higher resolution imagery the photo ID coordinates for the higher resolution imagery will be more reliable. However, the imagery resolution (basically the size of the pixel) does not necessarily directly equate to spatial accuracy. That is, a small pixel is no more and no less likely to be in the correct location than a large pixel. We did not test the Yellowstone River Corridor aerial photography, but relied on the metadata declaration that the imagery met National Map Accuracy Standards although the scale was not stated.

In our testing we determined the Digital Globe imagery was nearly 30% more accurate than the NAIP imagery, and had far more consistency across the image (variance across the NAIP was 2.5x greater than across the DG). The statistics are shown in the following chart.



The obvious conclusion is that the Digital Globe imagery will provide a more spatially accurate basis for adjusting the parcels. When using the Digital Globe imagery as a control for parcel alignment, the typical resultant parcel accuracy could be within the 1 meter (disregarding all other factors, such as survey and

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A STD. ERR. OF UNIT WGT. BETWEEN 0.5 AND 2.5 IS
CONSIDERED SUITABLE FOR MOST APPLICATIONS

The field surveys were carried out by Kurt Luebke, PLS, Steve Cummings and John Shirey. All data reduction and analysis was performed by Kurt Luebke, using Trimble Geomatics Office V1.61 software and Windows Geographic Measurement Management V1.01 software.

Six PLSS corners were surveyed around section 33, and these positions were then used to adjust the township. It would be expected that this would be more of a local adjustment around section 33 and the surrounding sections, than an adjustment for the whole township.

Although the pilot area was one section (T01N R25ESection 33) a GCDB adjustment was done on the entire townships. The pilot section had more control than one typically can find in urban area but this one section was not fully developed and most of the development was recent residential. Thus we were able to recover more PLSS monuments than one would typically expect. The GCDB adjustment improved the positional accuracy of the GCDB within the pilot area to an average error of 56 feet (~ 17 meters). The errors ranged from zero at the GPS control points, to 87 feet at some interior positions.

Post Adjustment GCDB Error Estimates:

Minimum: 0 ft

Maximum: 87 ft

Mean: 56 ft

Standard Deviation: 42 ft

The changes in error (from original BLM to adjusted DJ&A values) ranged from zero to 68 feet with an average change of 34 feet (~10 meters) over the section.

III. d Data not tested for positional accuracy

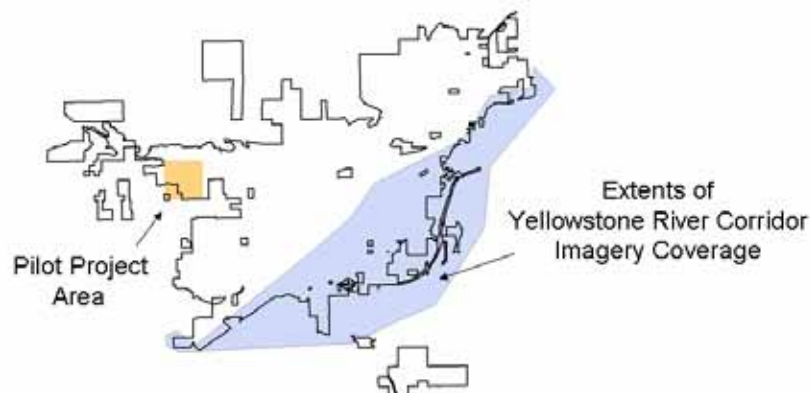
GPS Road Features:

Mapped roadway features such as curb lines, pavement edges, sidewalks, etc. were discussed...

Yellowstone River Corridor Imagery:

Aerial photography exists along the Yellowstone River Corridor. Photos are georeferenced and geo-rectified, and have a ground resolution of 0.3 meters, or approximately one foot. The photographs were taken on May 1 and 2, 2004. The accuracy was not tested in this project, however the metadata spatial accuracy statement states: *The orthoimagery output from these inputs meet National Map Accuracy Standards (NMAS)*. This statement does not declare the scale for which it meets this standard. However, 1 foot pixel resolution *typically* means a 1:2400 map scale. If this product does meet NMAS for 2400 scale mapping, then the positional accuracy would be 6.66 feet. NMAS specifies that 90% of measured points will be within the stated distance of their true location on the ground.

The accuracy of this imagery resolution is the best currently available in the City of Billings, but the coverage is not complete.



III. e Results Comparison

Billings has 3 categories of controls: GCDB, Aerial Imagery, and Road GPS Features.

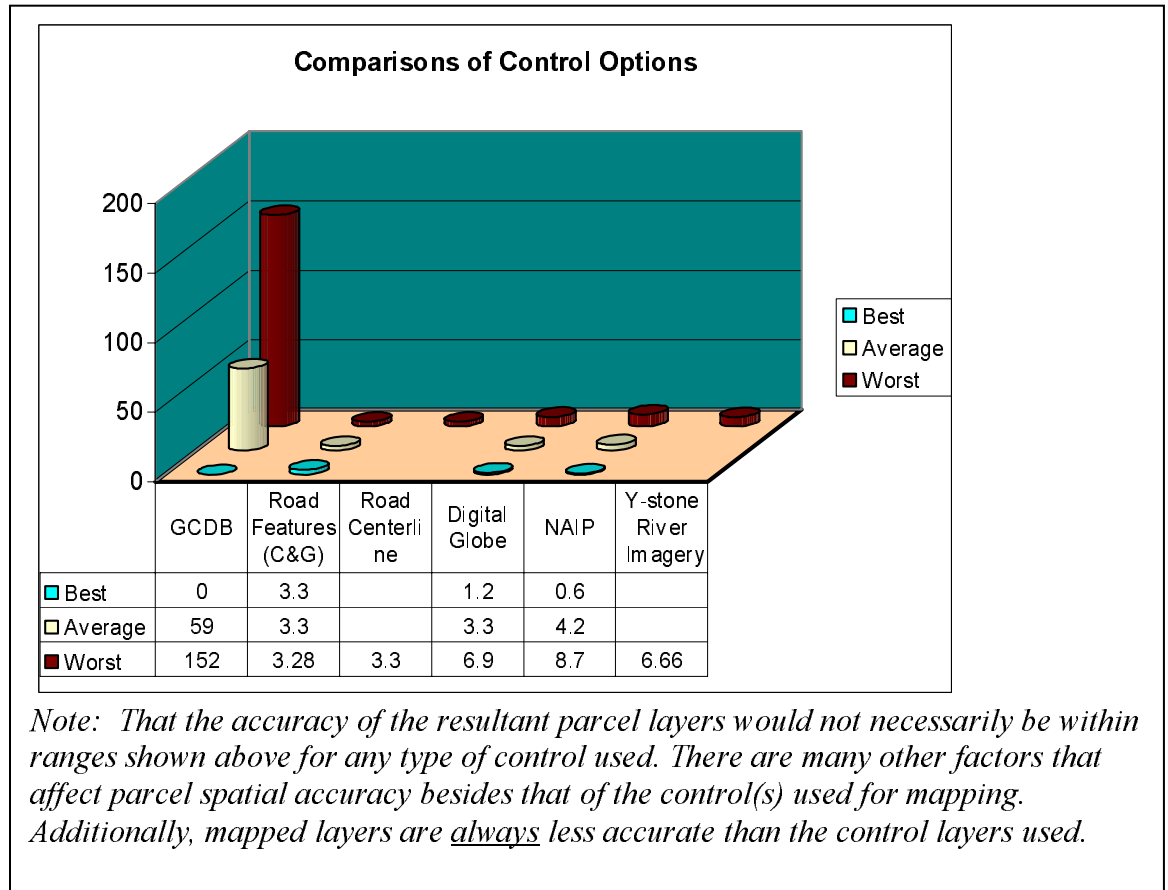
The GCDB adjustment done in the pilot project improved the accuracy by as much as 68 feet (~21 meters), resulting in an average GCDB accuracy of 56 feet (~17 meters) across the section. At best, parcels adjusted to the new GCDB would be accurate to GCDB values in the range from zero to eighty-seven feet (27 meters), depending on location within the section. This is not accurate enough for urban parcel densities. In urban areas positional errors greater than 30 feet (~10 meters) can place features on the wrong side of a street, which is evident in many parts of the city.



The aerial imagery, in particular the Digital Globe imagery, ranged in accuracy from 0.4 meters (~ ft) to 2.1 meters (~ 7 feet), with an average of 1.0 meter (~ 3 feet). Thus the Digital Globe aerial imagery provides a more accurate control - the typical resultant parcel accuracy could be within the 1 meter. Using the imagery as a control has the added advantage of visual coincidence - it looks better when the layers are overlaid.

The following chart compares the spatial accuracy of the various controls available to use in the City of Billings, which could be used to improve the positional accuracy of the parcel layer. In addition to the control shown in

this chart, field surveying of lot or subdivision corner monuments can be done in areas where other information is not adequate to control the parcels to the required accuracy.



GCDB based control provides the least benefit for urban and densely developed areas. The options in order of accuracy from best to worst are:

1. Field surveying with COGO (recapture data)
2. Field surveying with rubber-sheeting.
3. Road GPS (C&G) & Road Centerline
4. Yellowstone River Corridor Imagery
5. Digital Globe Satellite Imagery
6. National Agricultural Imagery (NAIP)
7. GCDB

The options in order of cost from lowest to highest are:

1. Adjust to photos and GIS features
2. GCDB adjustment

3. Field surveying & rubber sheeting
4. Field surveying & COGO from source records

III. f **Parcels Adjustment**

III.f.i **Adjustment to GCDB**

The best process for adjusting the parcel layer to the GCDB is to use a rubber sheeting utility that respects the GCDB coordinate points as controls. The MT DOA GIS office has a script that uses GCDB point unique identifiers as the reference to linkages between the parcel boundary vertices and the GCDB points. This utility automatically finds the GCDB point nearest to the corners, and then rubber sheets parcels to the GCDB points, distributing the

III.f.ii **Adjustment to Photography**

Parcel adjustment to photography is a block-by-block rubber sheeting to the best visual fit of parcel lines to features visible on the photography, such as road edges, backs of sidewalks, fence lines, etc. In some areas entire blocks can be shifted (translated) without any changes to the parcel geometry. In other areas parcel geometry must adjust within a block to best fit the imagery. Rural and undeveloped areas are more difficult to adjust to the photography where features that correlate with parcel boundaries (such as fence lines, or road ways) are fewer or non existent.

III.f.iii **Adjustment to Road GPS Data**

Parcel adjustment to the road GPS data uses the mapped road features such as alley aprons and curb & gutter lines as the control for block-by-block adjustments. These adjustments are similar to the photography adjustments in the way parcel geometry and position is handled. The city does not have complete road GPS data coverage of the entire city. Areas of new development, for instance, are not covered.

III. g **Other GIS Layers Adjustment**

Other GIS layers relate to the parcels or to the GCDB and will need to be adjusted to refit to changes that are made to the parcels.

The following list outlines some of those layers (*prepared by Tom Tully, GIS Coordinator, City of Billings, January 24, 2006*)

Yellowstone County and City/County Planning:

- 1) Zoning
- 2) School Districts
- 3) Election Wards
- 4) Precincts
- 5) Commissioner Districts

- 6) Neighborhood Task Force Areas
- 7) Neighborhoods
- 8) City/County Limits
- 9) Emergency Service Zones (ESNs)

City of Billings:

- 1) Lighting Districts
- 2) TIFID Boundaries
- 3) Historic District
- 4) Water Service area
- 5) Sewer Service area
- 6) Pressure Zones
- 7) Heights Water District
- 8) Drainage Basins – Sanitary Sewer
- 9) Billings Urban Fire Service Area (BUFSA)

GIS Data affected by accuracy of Tax Parcel/Lot boundaries:

- 1) Street centerlines
- 2) PW Utilities sewer and water infrastructure
- 3) PW Engineering/Street Traffic curbs, gutters, sidewalks, light poles, etc.
- 4) PW Engineering storm drains

III. h Cost/Benefit

Costs were estimated to perform rubber-sheeting adjustments to the city's existing aerial imagery and GIS features (C&G, and road centerline). The density of parcels per-section was taken into consideration because of the amount of time required and the complexity involved. The estimated costs per township were extrapolated across the four recommended red-line townships for the City of Billings with the following results.

Estimated Costs versus average expected resultant accuracy:

Method	Cost/township	Resutant Accuracy (ft)
Adjust to Photos & features	\$ 6,408	4
GCDB Adjust	\$ 11,794	59

The costs shown above include estimated costs to perform accuracy checks after the adjustments are done.

The cost to perform adequate GCDB adjustments is likely to be twice as expensive as a GCDB adjustment and the resultant reliability is far greater than a GCDB adjustment due to the accuracy of the data used for control (photos, GPS data, etc.).

Note:

The most accurate method for mapping the location of property boundaries in a GIS is to use Coordinate Geometry (COGO) methods to draft the record measurements from deeds, surveys and plats, and do field surveys of lot and block corners and other monumented property corners. Although this method provides the highest accuracy and long term usability it is typically, prohibitively expensive to do. Estimates for the cost to do this were not considered for the City of Billings.

Field surveying of block and lot corners and rights of way monumentation to control a rubber-sheeting or least squares adjustment could improve the parcel mapping to a high degree of reliability within each block, but again the costs are high to do this and thus were not estimated for this project.

Recommend scope of work:

1. ...

IV Conclusions

Urban areas require much greater spatial accuracy for GIS layers, including the cadastral layer, than do rural areas. This holds true for the City of Billings. In urban areas parcel densities increase, lot sizes get smaller, and more spatial information is collected and mapped than for rural or sub-urban areas. This project revealed that despite the need for higher accuracy in the City of Billings, the cadastral line work is less accurate than for other parts of the county and considerably less than some of the other GIS layers (such as curbs and gutters, water lines, etc.) that the city uses for operations. The disparity in spatial accuracy causes severe misalignments when the City parcel layer is used with other GIS information.

The City of Billings and Yellowstone County have options for how to improve the spatial accuracy of the parcel GIS layer in the City of Billings. GCDB methods requires acquiring additional survey control and possibly entering more up-to-date survey data from recorded plats and surveys, performing an adjustment and working the BLM to have the adjusted data incorporated into the GCDB.

Alternatively, other methods can be used adjust the parcels, and there exists sufficient reference data, such as aerial imagery and GPS road data, to use as mapping control to improve the placement of parcel boundaries and rights-of-way.

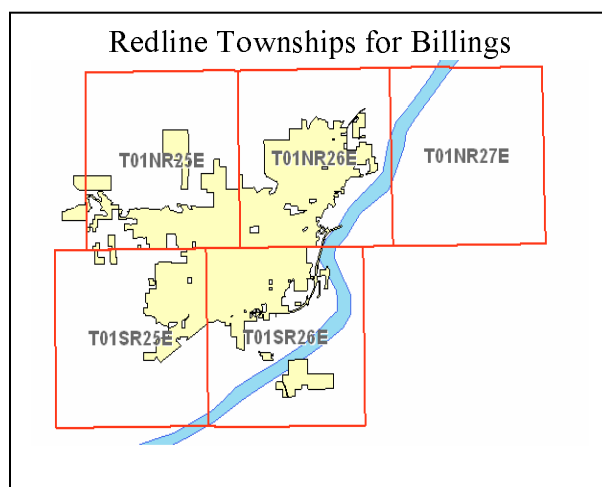
The City and County must agree how best to proceed and who shall be responsible for ensuring that the work moves forward in a satisfactory manner to improve the spatial alignment of the existing cadastral data.

Note on redline areas:

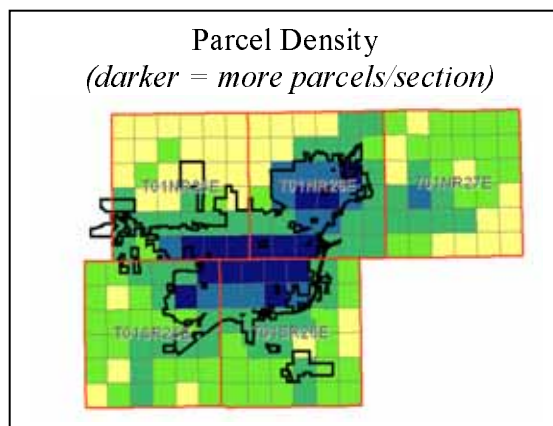
Redline areas "disconnect" the parcels from the GCDB, however, other layers, such as district boundaries, may follow the PLSS in their legal boundary descriptions. There may be incongruities between legal boundary descriptions that follow the PLSS and the parcel boundaries within the redline areas where the parcel boundary is supposed to follow the PLSS line. In those instances there may have to be dual representations of a line: a legal line and a GIS analysis line, in order to be able to show legal locations, and be able to do accurate GIS analysis.

v Recommendations

Because a GCDB based adjustment can not reliably improve the spatial accuracy of the cadastral layer in a cost-effective way, we recommend that Yellowstone County red-line the urban Billings area - that is, discontinue using the GCDB based adjustment process. Within the redline area other, more reliable and more effective method should be used to generate better results at lower costs than a GCDB method. The cadastral layer within the redline area can continue to edge-match to the GCDB on the township boundaries. Due to the township-by-township approach to the BLM's GCDB adjustment, we recommend that entire townships be redlined. For the City of Billings the most appropriate townships to redline are the five townships that contain the majority of the city limits.



Although there are rural areas within these townships, future growth may occur in these areas, and redline adjustment methods can still help to improve the rural areas as well.



Although the parcel density of these five townships varies and the availability of GIS data to use for control is not uniform throughout the townships, the GIS data and aerial imagery coverage can be used in combination to adjust the parcels.

The county should prioritize areas for adjustment within the city based on each section's parcel density and the spatial accuracy of the existing parcel data. The high density, low accuracy urban core should be the highest priority and receive the most attention.

Recommended Methods for Performing Immediate Adjustments

All parcels within the red-line area may be adjusted to existing GIS features and aerial imagery using the accuracy precedence listed below.

1. Road GPS (C&G) & Road Centerline
2. Yellowstone River Corridor Imagery
3. Digital Globe Satellite Imagery

This should be done on a block-by-block procedure, where the parcels within each block are translated and rotated to fit within the block, as best as can reasonably be done. Most blocks of parcels will fit satisfactorily with a simple translation and rotation (whole block moves together as a unit) to the correct location. The block perimeters are defined by GPS curb and gutter, GPS derived road centerlines, or as seen on the aerial imagery.

Some area will not be corrected using a simple translation and rotation to fit within blocks. These areas may require more work, such as a best fit (rubber-sheet) into and within the block or even re-drafting from the original plats. Bad areas result from either incorrect initial mapping (i.e. the assessor map was drafted incorrectly), or the digitizing work was in error, or the data is incomplete or positioned wrongly, or other reasons. If the data are so out of whack that it does not correctly represent the parcel geometry, it can, and should, be corrected. Any areas that fail to improve by translation and rotation or rubber-sheeting will probably have to be redrafted by re-digitizing, COGO-ing, inserting CAD data (if available) to replace the geometry with the good. This process will require user interaction and judgment in a block-by-block interactive process, but will yield the best results. Due to the individual idiosyncrasies of the problem areas, the Yellowstone County cartographer should review these on a block-by-block basis to make the determination of the best course of action.

Long Term Recommended Methods for Performing Adjustments

Correcting and improving the spatial accuracy of parcels within the red-line is simplified by removing the GCDB methods from the process. Within redline areas it is simple to identify an area such as a block or a section, as a target for improvement. That selected area can be isolated, corrected, and then the corrected geometry can be swapped into the cadastral fabric (at the county level) and transmitted to the state for update into the state-wide cadastral fabric. The city and county can work together to identify and correct specific areas for correction.

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